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A New Kind of Casing Material Could Be Used for Controlling Fly Populations in Mushroom Crops

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ABSTRACT

In Turkiye, sciarid and phorid species are the most common and most damaging insects encountered when growing mushrooms indoors. In the present study, the effectiveness of a newly patented casing soil on the population growth of most common sciarid [*Lycoriella ingenua* (Dufour)] and phorid [*Megaselia halterata* (Wood)] species was evaluated by comparing with a commonly used local (conventional) casing soil in two consecutive mushroom growing periods in 2025. Adult emergence and fruit damage rates by the larvae were used to evaluate the effectiveness of the treatments. The results showed that the mean number of emerging adults was significantly reduced by newly patented casing soil application in comparison to conventional casing soil application. In newly patented casing soil applications, reduction in adult emerge of both fly species ranged from 45.6% to 50.5% in the 1st growing period of the study and from 43.32% to 46.1% in the 2nd growing period. Newly patented casing soil application also resulted in significantly lower fruit damage rates in both growing periods (in both fly species: ranging from 9.6% to 10.9% in the 1st growing period and from 7.9% to 9.3% in the 2nd growing period) than the conventional casing soil application (from 18.2% to 21.1% in the 1st growing period and from 21.5% to 23.7% in the 2nd growing period). When both casing soil applications were compared in terms of yield values, there was not any significant difference between the two soil applications in both growing periods. However, the implementation of newly patented casing material resulted in a higher marketable mushroom yield and improved product quality, leading to higher market pricing. Overall findings indicate that newly patented casing soil could contribute to the management of *L. ingenua* and *M. halterata* populations in the cultivation of edible mushrooms.

Keywords: Mushroom cultivation, Mushroom flies, Newly patented casing soil, Turkiye.

INTRODUCTION

In recent years, mushroom cultivation has become one of the most fast-growing and profitable sectors of Turkish agriculture. In Turkiye, mushroom cultivation started with small-scale trials in the 1960s and reached commercial production levels from the 1980s onwards

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(Gunay and Abak, 1976). Thanks to the Turkish Ministry of Agriculture's support programs for rural areas, production volume has increased steadily over the last two decades, and reached 75.000 tons in 2024 (TUIK, 2025). *Agaricus bisporus* (Lange) Imbach (Agaricaceae) (known as 'white button mushroom') is the most commonly cultivated mushroom species, representing roughly 90% of the whole production, although chestnut, oyster, truffle, and morel mushrooms are traded in the country. Several mushrooms types, such as Lion's Mane, Reishi, Chaga, etc. are also produced for medicinal purposes (Erler and Polat, 2008; TUIK, 2025).

In Turkiye, mushroom flies are the most common and devastating insect pests of mushrooms, *Megaselia halterata* (Wood) (Phoridae) and *Lycoriella ingenua* (Dufour) (Sciaridae) being the most common species (Erler *et al*., 2009a; Erler *et al*., 2011; Erler and Polat, 2015). These fly groups are all typically found together in cellars used for mushroom cultivation and grow population after the casing soil is applied (Erler and Polat, 2008). Casing soil is one of the essential components that regulates the transition process between mycelium development and fruiting body (carpophore) formation in mushroom (*A. bisporus*) cultivation (Onel and Polat, 2025). Mushroom flies cause direct crop damage by larval feeding on compost, mycelium, and mushroom sporophores (fruiting bodies), and indirect damage by vectoring harmful pathogens and mites (Fletcher and Gaze, 2008; Shamshad, 2010; Rinker, 2017; Navarro *et al*., 2019; Navarro *et al*., 2021). In addition, the workers in the cellars are constantly disturbed by adult flies who enter their eyes, ears and nostrils.

The scientific literature provided details the olfactory and behavioral attraction of mushroom flies - specifically sciarid flies (*L. ingenua*) and phorid flies (*M. halterata*) - to specific mushroom-growing substrates, mycelial phases, and microbial volatiles. For example, Phase III and compost odors attract wild populations of sciarid and phorid flies, which can introduce pests into commercial operations early in the production cycle (Jess *et al.*, 2007). Female sciarid flies (*L. ingenua*) are significantly more attracted to unsterilized mushroom compost than to the actual white button mushroom (*A. bisporus*) fruiting bodies (Cloonan *et al.*, 2016). Phorid female flies (*M. halterata*) are heavily attracted to the spawn-running phase of mushroom production (Navarro *et al.*, 2021).

Current control of mushroom flies in Turkiye has largely relied on the use of synthetic chemical insecticides, leading to residue problems in harvested crops and resistance development in fly populations. In recent years, The Turkish Ministry of Agriculture has put strict regulations in place to control the use of pesticides in mushroom cultivation with the goal of lowering the risks to human health. For sustainable management of mushroom flies and

residue-free mushroom production, a lot of research has been carried out to develop innovative control agents that do not harm for non-target organisms. Erler *et al.* (2009a) tested 8 plant-based materials (six hot-water plant extracts and two commercial azadirachtin-based products) for the control of *M. halterata* populations in 3 consecutive growing periods, and they suggest that both azadrachtin-based products and two hot-water extracts [*Origanum onites* L. (Lamiaceae) and *Pimpinella anisum* L. (Apiaceae)] has the potential to suppress *M. halterata* populations in mushroom growing cellars. Erler *et al.* (2009b) evaluated two commercial microbial products [an entomopathogenic nematode, *Steinernema feltiae* (Filipjev) Wouts, Mracek, Gerdin & Bedding and a bacterial larvicide, *Bacillus thuringiensis* var. *israelensis* Berliner (Bti)] and reported that each of the microbial products reduced the incidence of fruit damage by the larvae and resulted in significantly lower damage rates when compared with the water-treated control. In a more recent study by Erler and Bayram (2022), a new electric light trap (so-called '*ecosav-M1*) was designed and evaluated for mass trapping of mushroom flies. Their findings revealed that using the new-designed light trap for mass trapping significantly decreased the amount of damage caused by the larvae to sporophores during both growing periods. In addition, cultural practices that focus on sanitation, exclusion, and environmental management to make the growing environment unfavorable for pests serve as the vital first line of defense in mushroom cultivation by proactively manipulating the growing environment to control mushroom flies (such as sciarid and phorid flies) before chemical intervention becomes necessary (Coles, 2002; Martín *et al.*, 2016; Navarro *et al.*, 2020). This study was conducted to evaluate, for the first time, a newly patented casing soil on the population growth of most common sciarid (*L. ingenua*) and phorid (*M. halterata*) species in two successive growing periods.

MATERIALS AND METHODS

Casing Soils

This study investigated the effectiveness of a newly patented casing soil on the population growth of most commonly encountered species of mushroom flies, namely *L. ingenua* and *M. halterata*, in comparison with a conventional (traditionally widely used) casing soil (Fig. 1). The new casing soil is a patented (Patent No. TR 2019 09514 B), eco-friendly, and sustainable mushroom casing developed by the 2nd and 3rd authors (Dr. Ersin Polat and Omer Onel) and consists of perlite as the main material, and liquid and solid vermicompost as supplements that serve as a peat-alternative for mushroom cultivation, offering superior water retention and supporting healthier mushroom development (Fig. 1a; Table 1). The conventional casing soil

used for comparison typically consisted of black peat adjusted to the suitable pH using calcium carbonate (Fig. 1b). While newly patented casing soil was prepared by the researchers throughout the study, the conventional casing soil was provided from a local compost company (SMS-Ersanlar Tarim Madencilik San. Tic. Ltd. Şti., Korkuteli, Antalya).



Figure 1. The casing soils used in the present study; Newly patented casing soil (**a**), and conventional (traditionally widely used in Turkiye) casing soil for comparison (**b**).

Table 1. Some physical and chemical properties of the two casing soils (CS) used in the study.

Property	Newly patented CS	Conventional CS
pH	8.04*	7.32
EC (mS cm^{-1})	1.70	1.20
Water-holding capacity (%)	235.50	59.60
Dry matter content (%)	32.80	49.52
Organic matter (%)	18.46	27.78
Total ash content (%)	81.54	72.22

*: Final pH value of newly patented CS ranged between 6.8 and 7.7.

Experimental Site and Design

This study was carried out in a mushroom growing cellar located within the Campus of Akdeniz University (Antalya) during two consecutive mushroom growing periods in 2025. The cellar had a similar design to those used in the local commercial mushroom companies but it had a lower capacity (approx. 15 m^2). In each growing period, a total of 40 polyethylene bags (each including approximately 10 kg of standard pasteurized and mycelium-inoculated compost

and having a surface area of 0.250 m^2) were used (Figure 2a). Each bag was considered as one replicate, and 10 replicates were used for each treatment. Four treatments were tested throughout the study period, and they were termed as 'Newly patented soil - *L. ingenua*', 'Conventional soil - *L. ingenua'*, 'Newly patented soil - *M. halterata*', and 'Conventional soil - *M. halterata*'. Since the experiments were conducted across two distinct mushroom growing periods, there were 20 replicates for each treatment in total. In both growing periods, experiments were carried out under the same conditions (temperature, humidity, carbon dioxide levels, ventilation, etc.).

Experiments

Ten pairs (10♀:10♂) of 48-h-old adults of *L. ingenua* or *M. halterata*, maintained in the Entomology Laboratory of Plant Protection Department of Akdeniz University, were transferred onto the casing layer of each polyethylene bag covered with a transparent nylon gauze cage (35 cm high) in dome shape (Fig. 2a). The insects were allowed to mate and lay eggs there for 96 h, after which all the insects were removed using an aspirator equipped with a vacuum source. All cultivation practices (Turkekul, 2023; Karaduman, 2025) throughout the experiments were applied in the same way as those used in commercial mushroom cultivation cellars in the Antalya-Korkuteli region.

The efficacy of the treatments was evaluated by counting the number of adults emerged from each bag in each treatment group and assessing the fruit damage caused by the larvae (mean number of fruits damaged by larvae in each treatment group) (Fig. 2b). For adult counts, at weekly intervals for 5 weeks after the first adults were seen, emerging flies from each bag in each treatment group were gathered with an aspirator equipped with a vacuum source and counted. The counts were recorded separately for each replicate (bag) in each treatment group at each sampling week. Adult emergence was reported as the number per bag for each treatment. In each growing period, mushroom fruits were harvested 6 times (2 per flush) to determine larval damage rate, and the number of fruits damaged by the larvae was recorded separately for each replicate in each treatment group at each harvest (Erler *et al.,* 2009a, b). The harvest of the fruiting bodies was carried out after the adults (flies) had been collected using an aspirator for the purpose of the weekly count.



Figure 2. Polyethylene bags, including pasteurized and spawned compost, covered with a transparent nylon gauze cage in dome shape, used in the study (**a**), and fruit damaged (in circle) by the larvae of *Lycoriella ingenua* or *Megaselia halterata* (**b**).

Data Analysis

Since all experimental procedures and data collection were carried out under the same conditions (temperature, humidity, carbon dioxide levels, ventilation, harvest times after fruiting, etc.) during the both growing periods, in the data analysis, the effects of treatment, species, growing period, sampling time, and their interactions were not examined in the analysis. The ANOVA test was used to analyze the data regarding the larval damage rates and adult emergence rates (SAS Institute 2001). The Tukey's test ($P<0.05$) was used to compare treatment means and to determine statistically significant differences. In both growing periods,

weekly mean numbers (the average number of flies collected from each replicate every week) of emerging adults of *L. ingenua* and *M. halterata* in each treatment are presented here in graphical form. The efficacy of newly patented casing soil treatments on adult emergence of both fly species in each of the two growing periods was calculated with the formula;

$$\% \text{ Reduction} = [(\bar{Y}-Xi) / \bar{Y}] \times 100$$

where Xi is the total number of emerging adults in each of the newly patented casing soil treatments, and $\bar{Y}$ is the total number of emerging adults in each of the conventional casing soil treatments used for comparison (Erler *et al.*, 2009a).

Larval damage over the two growing periods was expressed as the percentage of fruits damaged by larvae for each treatment, and the following formula was used to determine percentage damage incidence (Erler *et al.*, 2009a, Erler *et al.*, 2011).

$$\%\text{Damage} = (\text{Number of fruits damaged} / \text{Total number of fruits}) \times 100$$

Prior to analysis, mean percentages subjected to square-root transformation, and the Tukey's test was used to compare treatment means and to determine statistically significant differences ($P < 0.05$). Mushroom yield values in each of the two growing periods were also presented in the paper. For each treatment, yields for each flush and total yield (the sum of the two flushes), were presented here in kg/m^2. Following yield data analysis, the Tukey's test ($P<0.05$) was used to compare and differentiate treatment means.

RESULTS

Emerging Adult Counts

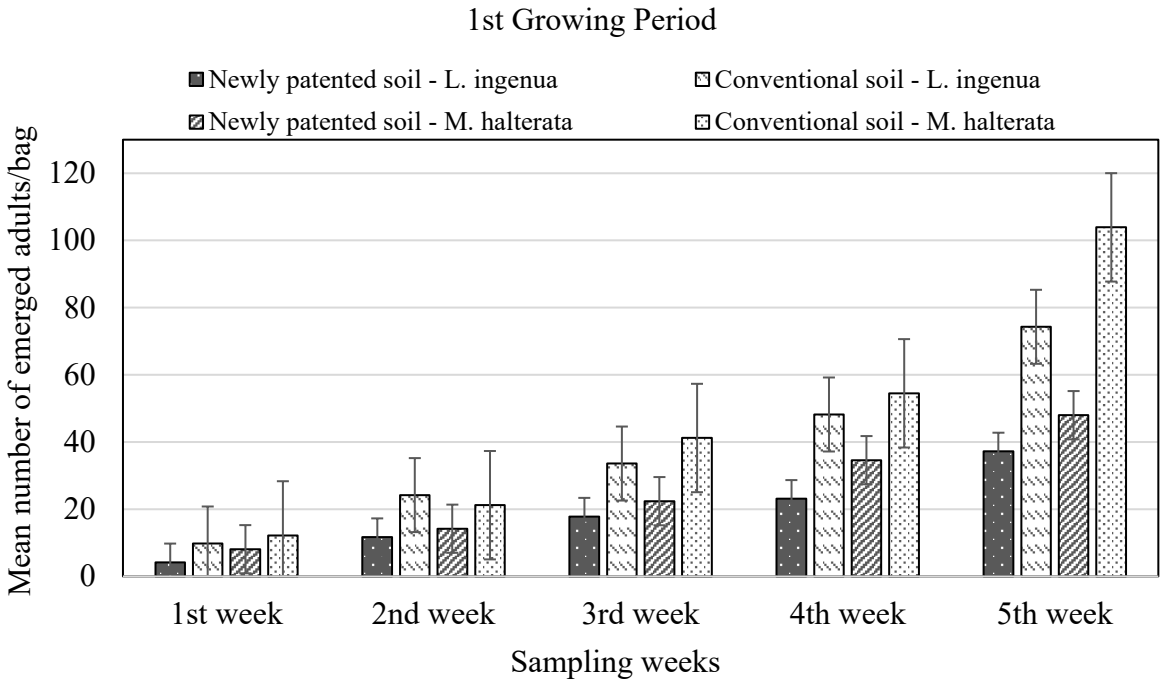
Weekly mean numbers of emerging adults of *L. ingenua* and *M. halterata* in each casing soil treatment are shown in Fig. 3. In both mushroom growing periods, application of newly patented casing soil resulted in reduced adult emergence in both mushroom fly species tested compared with conventional casing soil. Weekly mean numbers of both adult *L. ingenua* and *M. halterata* that emerged from newly patented casing soil treatments were significantly lower throughout the sampling period in two successive mushroom growing periods than those from conventional casing soil treatments ($P < 0.05$). However, the mean numbers of both fly species emerged from both newly patented and conventional casing soil treatments increased significantly from week to week in both growing periods (Fig. 3).

When newly patented casing soil is evaluated in terms of reduction in adult emergence (RAE) rates, treatments with newly patented casing soil in both growing periods reduced adult emergence in *L. ingenua* by 50.5 and 43.3% and in *M. halterata* by 45.6 and 46.1%, respectively (Table 2).

Larval Damage Rates

Table 2 also shows fruit damage rates (FDR%) by the larvae of both *L. ingenua* and *M. halterata* in both newly patented and conventional casing soil treatments in both growing periods. In comparison with conventional casing soil treatment, newly patented casing soil treatment significantly reduced the incidence of fruit damage by the larvae of both fly species in each of the two growing periods ($P < 0.05$). Based on the mean number of mushrooms damaged by the larvae, the efficacy of each of the two soil treatments changed only slightly with successive growing period. However, no statistically significant difference was observed in both growing periods in terms of larval damage rates in each of the two casing soil treatments applied to each of the two mushroom fly species.

Over the course of a 25-day harvesting period in each of the two growing periods, there were three flushes of mushrooms; however, because of fungal and bacterial disease outbreaks in all treatments (though a bit more severely in conventional plots), the third flush data were not considered. Table 3 shows the yield for each flush as well as the cumulative flushes (total yield) for each treatment. When both casing soil applications were compared in terms of total yield values, no significant difference was observed between new patented and conventional casing soil treatments in both growing periods ($P < 0.05$).



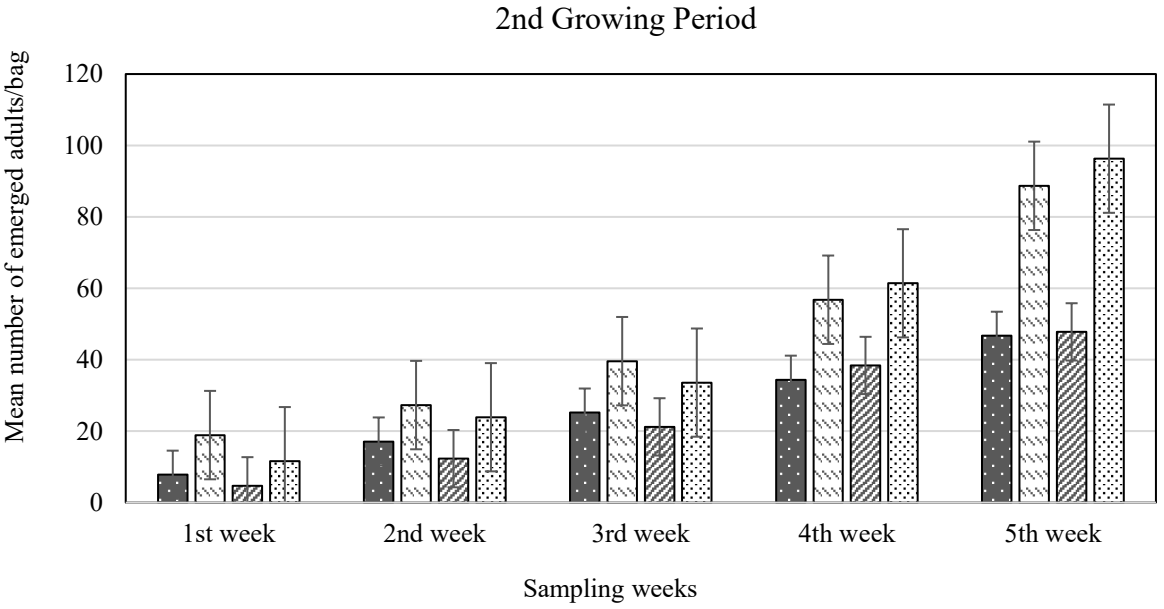


Figure 3. Mean number (± SE) of emerging adult *Lycoriella ingenua* and *Megaselia halterata* per bag in the treatments at each sampling week in each mushroom growing period. There were 10 bags (replicates) for each treatment in each of the two growing periods (n: 10). In each growing period, means with the same upper-case letter in the same sampling week do not differ significantly (Tukey's test; $P < 0.05$). In each growing period, means with the same lower-case letter in the same treatment do not differ significantly (Tukey's test; $P < 0.05$).

Table 2. Percentage reductions in adult emergence of *Lycoriella ingenua* and *Megaselia halterata* in the newly patented casing soil treatments, and mean percentages (± SE) of fruits damaged by larvae in the treatments in each of two growing periods*

Treatments	Reduction in adult emergence (RAE), and fruit damage rate (FDR) 1st Growing Period		2nd Growing Period	
	RAE (%)	FDR (%)	RAE (%)	FDR (%)
Newly patented casing soil - *L. ingenua*	50.5	9.6±3.4 Ba	43.3	7.9±2.6 Ba
Conventional soil - *L. ingenua*	-	18.2±5.8 Aa	-	21.5±6.2 Aa
Newly patented casing soil - *M. halterata*	45.6	10.9±2.3 Ba	46.1	9.3±3.3 Ba
Conventional soil - *M. halterata*	-	21.1±4.7 Aa	-	23.7±4.3 Aa

* RAE (%): Since the data wasn't analyzed statistically, we cannot calculate the SE to check the experiment's validity. For fruit damage rate, n=6 in each growing period. In terms of fruit damage rates in each growing period, means within a column followed by the same capital letter are not significantly different (Tukey's test; $P < 0.05$). When fruit damage rates in both growing periods are compared with each other, means within a line followed by the same lower-case letter are not significantly different (Tukey's test; $P < 0.05$).

Table 3. Yield (kg/m^2) obtained from the newly patented and conventional casing soil treatments against the two common mushroom fly species (*Lycoriella ingenua* and *Megaselia halterata*) in two successive growing periods (mean yield ± SE).

Treatments	1st flush yield	2nd flush yield	Total yield	%Productivity (yield rate/40 kg compost)
		1st Growing Period		
Newly patented soil - *L. ingenua*	6.72±0.6 Aa*	3.76±0.3 Ab	10.48±0.7 A	26.2
Conventional soil - *L. ingenua*	6.48±0.4 Aa	3.92±0.2 Ab	10.40±0.5 A	26
Newly patented soil - *M. halterata*	6.60±0.6 Aa	3.52±0.1 Ab	10.12±0.4 A	25.3
Conventional soil - *M. halterata*	6.44±0.3 Aa	3.76±0.2 Ab	10.20±0.5 A	25.5
		2nd Growing Period		
Newly patented soil - *L. ingenua*	6.64±0.3 Aa	3.08±0.3 Bb	9.72±0.9 A	24.3
Conventional soil - *L. ingenua*	6.76±0.6 Aa	2.92±0.2 Bb	9.68±0.8 A	24.2
Newly patented soil - *M. halterata*	6.48±0.6 Aa	3.12±0.2 Bb	9.60±0.7 A	24.0
Conventional soil - *M. halterata*	6.64±0.7 Aa	3.04±0.3 Bb	9.68±0.9 A	24.2

* In terms of yield values in each of the two growing periods, means within a column followed by the same capital letter are not significantly different (Tukey's test; $P < 0.05$); In terms of yield values in both flushes, means within a line followed by the same lower-case letter are not significantly different (Tukey's test; $P < 0.05$).

DISCUSSION AND CONCLUSIONS

Casing soil, a critical component in the cultivation of button mushrooms (*Agaricus* spp.) and the top layer applied over mushroom compost after colonization to induce fruiting, maintains the necessary moisture levels for successful and uniform crops (Onel and Polat 2025). Many sciarid and phorid fly species, including *L. ingenua* and *M. halterata* tested in this study, that are major pests of cultivated mushrooms, lay their eggs directly into casing soil, and their emerging larvae cause significant yield losses (Erler and Polat 2015).

Not only in Turkiye but also worldwide, there are a limited number of crop protection products available for use in mushroom cultivation. Therefore, mushroom producers don't have much choice in what class of pesticides is used against mushroom flies and often face significant constraints in pesticide selection (Erler and Polat, 2008; Shamshad et al., 2009; Erler

and Polat, 2015). At the same time, increasingly stringent government regulations regarding pesticides and consumer pressure groups discourage the use of existing pesticides due to concerns about human health and the environment, implying that utilizing alternative and environmentally friendly control agents/strategies in the control of mushroom flies is necessary. Therefore, as a more sustainable approach, in this study we tested the effect of a newly patented casing soil on the population development of most common sciarid (*L. ingenua*) and phorid (*M. halterata*) fly species in the Antalya-Korkuteli district.

Results from the present study showed that newly patented casing soil treatments in the two successive growing periods reduced sciarid and phorid adult emergence and larval damage to mushroom fruits (Fig. 3, Table 2). Our overall results suggest that newly patented casing soil treatments may help to control the populations of both fly species tested by reducing adult emergence and may provide an alternative to currently used synthetic chemical insecticides in the cultivation of button mushrooms.

Our literature review revealed that the choice and preparation of casing soils directly influence the attraction, survival, and reproduction of mushroom flies like sciarids (*Lycoriella* spp.) and phorids (*Megaselia* spp.). In a study by Tibbles *et al.* (2005), *M. halterata* and another scarid species, *Lycoriella castanescens* (Lengersdorf) showed distinct behavioral responses and oviposition preferences when exposed to different casing substrates. They reported that both insect species rely on volatile organic compounds emitted from the substrates to locate potential breeding and egg-laying sites. Similarly, it is reported that organic matter-rich surface soils actively attract adult female flies seeking egg-laying sites, as they retain a moist microclimate and microbial odors resulting from fermentation (Infonet, 2025). Casing layers with loose and coarse structures allow adult flies easy access to lay eggs deeper into the profile near the colonized compost. Additionally, lighter, well-drained casing soils reduce localized anaerobic swampy pockets, whereas waterlogged heavy soils create high-moisture microzones that accelerate larval population (Navarro *et al.*, 2021). Cloonan *et al.* (2016) reported that females of *Lycoriella* spp. are attracted to the parasitic green mold, *Trichoderma* spp. growing in casing layers. As for the effect of newly patented casing soil treatments on the population growth of both mushroom flies studied, we believe that the changes in the color and structure of the casing layer by the application of newly patented casing soil may be responsible for reduced oviposition, leading to a decrease in the number of emerging adults. Adults of mushroom flies are known to respond visually to colors and white and red surfaces generally attract the lowest number of mushroom flies (*Sahin et al.*, 2016). In the present study, we observed that gravid

females visited the white surface where newly patented casing soil was applied (Fig. 1), but then immediately moved away. This indicates that females attempted to settle on the white surface of newly patented soil application, but were then repelled by the treated surface. Although alterations in the color or surface texture of casing layer by the application of newly patented soil are plausible mechanisms for reduced oviposition, leading to a decrease in the number of emerging adults, further research on these and other possible mechanisms of action is needed. Mushroom flies (such as phorids and sciarids) also select oviposition sites based on olfactory cues and nutrient-rich locations that provide food for larvae, often focusing on the top layer of compost or casing soil (Chandler *et al.*, 2002). We also believe that newly patented casing soil application could hindered olfactory attractants used as a cue by gravid adults of mushroom flies in selecting their oviposition sites.

In conclusion, based on the results of the present study, the use of newly patented casing soil, in conjunction with good management (in the form of compost pasteurization, fumigation of rooms, general good hygiene, and fly screening, etc.) could be useful for the control of mushroom flies by decreasing adult emergence and larval damage rates and may enable insecticide-free mushroom production.

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